



**Coláiste na Tríonóide, Baile Átha Cliath**  
**Trinity College Dublin**

Ollscoil Átha Cliath | The University of Dublin

**FACULTY OF SCIENCE, TECHNOLOGY, ENGINEERING AND  
MATHEMATICS**

**SCHOOL OF ENGINEERING**

**Electronic and Electrical Engineering**

**Engineering**  
**Senior Sophister**

**Semester 1, 2021**

**Next Generation Networks**

**14/12/2021**

**RDS Simmonscourt**

**14:00–16:00**

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**Instructions to Candidates:**

Answer TWO questions from Part A, TWO questions from part B, FOUR question from part C and FOUR questions from part D.

If you answer more than FOUR questions from part C and more than FOUR questions from part D, only the worst FOUR answers will be considered in the marks calculation.

**Materials permitted for this examination:**

This is a closed book examination. Materials Permitted: Calculator; Mathematical Tables.

**PART A [36 marks]****Q.1****[Total: 18 marks]**

**(a)** Describe the following wireless channel impairments:

**(i)** Path loss.

**[3 marks]**

**(ii)** Shadowing.

**[3 marks]**

**(iii)** Multipath.

**[3 marks]**

**(b)** Describe the following wireless channel mitigation techniques:

**(iv)** Diversity.

**[3 marks]**

**(v)** Directional antennas.

**[3 marks]**

**(vi)** Coding and modulation.

**[3 marks]****Q.2****[Total: 18 marks]**

**(a)** In a single server - finite buffer system, arrivals can be modelled as a Poisson process with rate  $4 \text{ s}^{-1}$  and the service times are exponentially distributed with mean 0.2 s.

**(i)** Give the Kendall's notation (motivating your choice).

**[2.5 marks]**

**(ii)** Calculate the average number of customers in the system, assuming the maximum capacity of the system is 3 customers.

**[2.5 marks]**

**(iii)** Calculate the blocking probability.

**[2.5 marks]**

**(iv)** Calculate the rate of rejected customers.

**[1.5 marks]**

- (b)** In a certain system the arrivals, which can be modelled as a Poisson process, occur at a rate of one every 150 ms, and the service times are exponentially distributed with mean 1.5 s. Also, there is no limit in the number of servers available.
- (i)** Give the Kendall's notation, motivating your choice [3 marks]
- (ii)** Calculate the average number of customers in the system. [3 marks]
- (iii)** Calculate the average delay per customer. [1.5 marks]
- (iv)** Calculate the average queuing delay. What do you notice? Why it is so? [1.5 marks]

**Q.3****[Total: 18 marks]**

The following system components are available:

- Multiple antenna schemes: spatial diversity-only mode with a spatial rate of 1, spatial multiplexing-only mode with a spatial rate of 2;
- Modulation schemes: 16-QAM, 64-QAM; 256-QAM;
- Channel coding: rate 1/3 code, rate 1/2 code;
- Bandwidth: 100 MHz, 200 MHz, 500 MHz.

- (a)** One wants to achieve a throughput equal to 1 Gbps or higher. Outline two systems to achieve this performance using the components above. [5 marks]
- (b)** In case you want to maximise the performance of users that are on average far away from the base station, what values (choosing between 'high' and 'low') of coding rate, modulation order and MIMO spatial rate should you choose? (motivate your answer) What will be the impact of the choice above on the system's spectral efficiency? [6 marks]
- (c)** In the following equation:

$$C = m \cdot B \log_2 \left( 1 + \frac{S}{N} \right) \quad (1)$$

C represents the channel capacity [bps], B the system bandwidth [Hz], S the useful signal power [W], N the noise power [W], and  $m = R_s \cdot O_m \cdot R_c$ , where

$R_s$  is the multiple antenna spatial rate,  $O_m$  is the modulation order [bits / modulated symbol] and  $R_c$  is the channel coding rate. Assume that  $\frac{S}{N} = 1$ .

Now suppose an adaptive system can switch among the configurations A and B below, depending on whether the Channel Quality Indicator (CQI) takes on the discrete values of 'good' or 'poor'.

- A = {spatial rate = 1, 16-QAM modulation, 1/3 channel coding rate, 100 MHz bandwidth};
- B = {spatial rate = 3, 256-QAM modulation, 2/3 channel coding rate, 500 MHz bandwidth}.

Assume that the receiver (user equipment) spends one third of the time close to the cell edge, and two thirds of the time close to the serving base station.

Calculate the average capacity of the adaptive system.

**[7 marks]**

## **PART B [36 marks]**

**Q.4**

**[Total: 18 marks]**

- a)** Describe the rationale behind the evolution of broadband access networks from ADSL to Passive Optical Networks (PONs), and how this relates the Shannon law of capacity.

**[5 marks]**

- b)** Describe how the different models of access network sharing have evolved, emphasising pros and cons of each model.

**[5 marks]**

- c)** Describe pro and cons of using point to point versus PONs to transport data from 5G base stations, taking in consideration the following RAN splits: E, D and B.

**[8 Marks]**

**Q.5****[Total: 18 marks]**

Quality of service is an important aspect of computer networks, enabling management of traffic flows with different priorities.

**a)** Provide a solution, using any appropriate quality of service tool, to the following problem. You need to process three traffic flows:

- Flow 1 should have a Committed Information Rate (CIR) of 7 Gb/s and Peak Information Rate (PIR) of 9 Gb/s. Flow 2 a CIR of 4Gb/s and PIR of 6Gb/s and Flow 3 a CIR of 1Gb/s and PIR of 2Gb/s.
- Relative priority is established for CIR packets only: Packets from Flow 1 are served at rate two times higher than packets from Flow 2 and Flow 3. Packets from Flow 2 and Flow 3 have similar priority.
- CIR packets have strict priority over PIR packets. PIR packets all get same priority.
- Show, using appropriate detailed diagrams and explanations, how you would use a chain of different QoS tools to implement your solution. Provide detailed information of any parameters required for any of the QoS tools.

**[10 marks]**

**b)** Provide a solution, using any appropriate quality of service tool, to the following problem. You need to process two traffic flows: Flow 1 carries mission critical data and Flow 2 carries video streaming traffic, both operating over the Internet:

- Any rate above 4Gb/s for Flow 1 needs to be dropped and any rate above 2 Gb/s for Flow 2 needs to be dropped.
- Flow 1 has always higher priority than Flow 2.
- The system needs to implement a system to avoid sudden drop of many TCP packets on congestion, so it needs to progressively drop packets as the queue gets full. Packets from Flow 1 needs to be dropped at lower rate than Flow 2.
- Finally, the output port can support a maximum rate of 5Gb/s.
- Show, using appropriate detailed diagrams and explanations, how you would use a chain of different QoS tools to implement your solution. Provide detailed information of any parameters required for any of the QoS tools.

**[8 marks]**

**Q.6****[Total: 18 marks]**

An optical signal has a data rate of 20Gb/s and is transmitted over a single mode fibre with dispersion coefficient of 17ps/km/nm and a loss of 0.25 dB/km.

- a)** If the bandwidth of the signal is 40 GHz, what is the maximum distance allowed, if the maximum tolerable broadening of the pulse is 30% of the time slot duration? (Assume the following conversion ratio: 100 GHz = 0.8 nm).

**[9 marks]**

- b)** Assume you need to design a link of 80 km length. Calculate the length of dispersion compensating fibre (DCF) required to keep the system dispersion within 10% of slot time duration. The DCF has coefficient of -120ps/km/nm.

**[9 Marks]****PART C [14 marks]**

**For each question you pick, select only ONE answer out of the four available options. Please ONLY answer FOUR questions**

**Q.7**

Which one among the following options is a wireless channel mitigation technique?

- a)** Path loss
- b)** Shadowing
- c)** Multipath fading
- d)** Code planning

**[3.5 marks]**

**Q.8**

Which one among the following functionalities does **not** belong to the OSI network layer?

- a) Medium access
- b) Routing
- c) Handover
- d) Device location

**[3.5 marks]**

**Q.9**

Which one among the following technologies is the **least** suitable for wireless wide area networks?

- a) 5G
- b) 4G
- c) Terahertz
- d) LoRa

**[3.5 marks]**

**Q.10**

In the Kendall's notation a/b/m/K, what is 'b' indicating?

- a) Service time distribution
- b) Number of servers
- c) Maximum number of customers allowed
- d) Type of arrival process

**[3.5 marks]**

**Q.11**

What category of the Agent Based Modeling (ABM) cycle would the choice of modulation at your transmitter fit into?

- a) Get stimulus
- b) Process stimulus

- c) Act
- d) None of the above

**[3.5 marks]**

**Q.12**

Which one among the following options, would likely be most suitable to comply with the requirements of Ultra Reliable & Low Latency Communication systems?

- a) Spatial multiplexing & 64-QAM
- b) Spatial multiplexing & QPSK
- c) Spatial multiplexing & 16-QAM
- d) Spatial multiplexing & 256-QAM

**[3.5 marks]**

**Q.13**

Which one among the statements about schedulers is **incorrect**?

- a) Round robin is simple in terms of implementation
- b) Maximum C/I is well suited for HD video streaming
- c) Proportional fair is not in use in 4G systems
- d) WiFi scheduling is fundamentally different as compared to the scheduling used by cellular systems

**[3.5 marks]**

**Q.14**

Which of the following options is helpful in increasing the data rate?

- a) Using higher order modulation
- b) Employing a frequency mitigation technique
- c) Increasing the number of antennas used in the mobile phone
- d) All of the above

**[3.5 marks]**



**PART D [14 marks]**

**For each question you pick, select only ONE answer out of the four available options. Please ONLY answer FOUR questions**

**Q.15**

Why is chromatic dispersion an issue for optical fibre transmission in telecommunications networks?

- a) Because it cannot be compensated
- b) Because its effect is worse than modal dispersion
- c) Because it increases the transmission loss
- d) Because it creates inter-symbol interference

**[3.5 marks]**

**Q.16**

Which of the following can be a major reason to prefer split II<sub>D</sub> to split E in a Cloud-RAN functional split system?

- a) It requires a smaller unit at the antenna site
- b) It requires lower power at the antenna site
- c) It could be transmitted over a Passive Optical Network (PON)
- d) It requires much lower fronthaul latency

**[3.5 marks]**

**Q.17**

What is the scope of a Cooperative Dynamic Bandwidth Assignment (Co-DBA) algorithm?

- a) To provide a bandwidth map allocation without waiting for a DBRu message from the ONU
- b) To predict packet arrival at the mobile handset
- c) To decide how much assured capacity should an ONU receive
- d) To assess the distance of each ONU from the OLT

**Q.18**

Which of the following Quality of Service (QoS) tools provides progressive packet drop to reduce the issues created by the TCP congestion algorithm?

- a)** Traffic policer
- b)** Strict priority queuing
- c)** Priority-based deficit weighted round robin (PB-DWRR)
- d)** Random Early Discard

[3.5 marks]

**Q.19**

Which of the following is the biggest advantage of Cloud-RAN

- a)** Statistical multiplexing of antenna sites
- b)** Statistical multiplexing of computing resources
- c)** Requiring lower capacity on the fibre connection network
- d)** Providing higher capacity over distributed RANs

[3.5 marks]

**Q.20**

Which of the following statements is false about optical amplifiers?

- a)** They decrease the Optical Signal to Noise Ratio (OSNR)
- b)** They add thermal noise
- c)** They can be deployed in a chain configuration to reach longer distance
- d)** One amplifier can be used for multiple wavelength channels

[3.5 marks]

**Q.21**

What is the purpose of a Forward Equivalence Class (FEC) in MPLS?

- a)** To map IP flows into MPLS tunnels
- b)** To update the time to live field of the header
- c)** To distribute labels across switches
- d)** To create stacked tunnels of IP flows

**[3.5 marks]**

**Q.22**

Which part of the packet header differentiates 802.1Q from standard Ethernet switching:

- a)** The preamble
- b)** The payload
- c)** The destination address
- d)** The VLAN header

**[3.5 marks]**